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COMETS:—THEIR COMPOSITION, PURPOSE AND EFFECT UPON THE EARTH.

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Though modern science has taught us much concerning the physical nature of comets, no one has yet been able to construct a theory which is either complete or free from objection. With these facts in view, and so far as possible within our brief limits, and without the use of technical language, we will endeavor to outline some of the more important results of observation and reflection upon this subject. We shall be obliged to draw freely from the results elaborated during the last fifty years by Bessel, Winnecke, Bond, Newton, Zœllner, Bredichin, and many others, without reference to individual authorities, or digressions upon rival theories and claims.

About twenty years ago it was proved that certain annually recurring displays of meteors are due to swarms of small bodies, which revolve about the Sun in elliptical paths, so situated in space as to encounter the earth at nearly the same time in each succeeding year. These paths or orbits were found to be identical in some cases with those of certain well-known comets. The conclusion seemed irresistible and is now accepted, that shooting stars or meteoroids, are simply the offspring of disintegrated comets.

Most likely, aerolites [large meteors] which sometimes reach the surface of the earth, are of the same origin. These bodies usually enter our earth with velocities [relative to the earth] ranging from twenty to forty-five miles per second. In consequence of the inconceivable heat which would be generated by such contact—manifested by the fiery train they leave behind—the smaller meteors, however dense, would be at once converted into impalpable vapor. Only the larger ones could survive the tremendous encounter, and reach the earth. Still others, composed of more fusible substance, though very large, may be unable to either overcome the mechanical resistance of the air, or the transcendent heat produced. Furthermore, that fiery ordeal must strip aerolites of all volatile matter and leave only refractory substances behind. Hence, analysis of meteoric stones must give us an idea of the real

composition of comets which would be totally misleading; just as the ruins of a house, destroyed by fire, would be no index of the chemical composition of all the material it contained before the disaster.

The Spectroscope [light analyzer] rather reluctantly yields some testimony as to the chemical and physical nature of comets. It seems to show that the nucleus is a solid or liquid incandescent [at a glowing temperature] mass. It proves quite conclusively that the matter surrounding the nucleus contains hydrogen and carbon in one of their numerous compounds. The flame of the Bunsen burner, which contains one of the compounds, shows a spectrum, [light analysis] which is very similar to, if not identical with, that observed in comets. Some observers have reported that these elements give evidence of their presence in the tails of comets at considerable distances from the head. If so, we must suppose the attenuated matter of the tail to be self-luminous. This may be attributed to some form of electrical action; since, considering the low temperature of space, it cannot be due to incandescence produced by ordinary heat.

Recent observations with the spectroscope seem to prove that a part of the light from comets is really reflected sunlight, since it faintly exhibits a spectrum like that of other bodies, which shine by reflected light alone.

The Polariscope [instrument for detecting reflected light] also gives evidence which leads to the same conclusion. The use of this instrument in examining faint sources of light is attended with great difficulties; and in the present connection, the records of different observers are not strictly harmonious.

Comets are seen in their simplest forms as faint patches of nebulous light. They are usually circular or oval in outline, without remarkable difference of brightness from center to circumference. At a later stage of development the comet shows a diffused brightness in its central parts, known as central condensation.

When a large comet approaches the Sun, the structure becomes far more complex. The center condensation gathers intensity. Finally, a point or disc of light appears near its center, which shines with a light approximating that of the planets. This is called the nucleus.

Observers with powerful telescopes usually find that what we commonly call the nucleus has no definite magnitude. It continually measures less with increase

of optical power. The inference is that the real nucleus, if it consists of a single solid body, must be very small, and must be obscured by the vapors which surround it. Generally the nucleus appears to shrink in size as it approaches the Sun. The most plausible explanation seems to be, that with lessened distance from the Sun, the real nucleus gets hotter and brighter and that at the same time, the vapors near it become more transparent. Other explanations have been offered which we have no space to consider.

We commonly find that the coma [nebulous matter about the nucleus] appears much brighter on the sunward side. In many cases, streams of matter appear to issue from the nucleus on that side. These assume a variety of forms, and are almost always curved backward, from the direction of the Sun at their extremities. Above the streams or jets, are sometimes seen one or more arcs of light, concentric with the nucleus from which they appear to recede,—just as waves recede in widening circles from a stone dropped into still water. These envelopes, as they are called, are supposed to be hollow spherical segments of matter, more dense than the surrounding parts of the coma.

One highly important characteristic of the matter which surrounds the nucleus is well established. The rays of light from different stars seen through it are not sensibly bent, or refracted. This shows that gases of an appreciable amount do not exist in comets.

The strange appearance of the tail and the gigantic dimensions it sometimes attains, are well calculated to arrest the attention of mankind. It is not wonderful that the ancients should have regarded it with trembling apprehension, nor is it surprising that, even yet, it excites an absorping curiosity among the educated, and the superstitious terrors of the ignorant. The matter of which it is composed must be expanded to an almost inconceivable degree; for even when it is millions of miles in diameter, the light of the faintest stars is seen through it with scarcely diminished brightness.

Near the head, it often appears to consist of two streams of matter issuing from either side of the coma with a dark channel of separation between. The tail at this point generally appears to have the same diameter from whatever direction in space it is viewed. We must, therefore, conclude that its interior is nearly or quite free from matter, and that like a hollow cylinder, or portion of a cone, as far as the dark channel extends. Beyond that point we may suppose that the

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interior fills up by gradual diffusion from the circumference. In some cases, and especially with small comets, the dark channel is wholly wanting, or but faintly indicated.

In order to give an idea of the situation of the tail in space, let us imagine the line from the Sun continually prolonged through the moving head of a comet into space beyond. We shall always find the tail extending nearly opposite the Sun, in the general direction of this prolongation, but curved more or less backward from it, in the direction from which the comet is moving. Sometimes we find more than one tail—each distinguished by the degree of its backward inclination. They have, indeed, been classified on this ground and found conformable to three general types.

The facts thus far presented prove nothing as to the origin of comets. The question demands for its solution mathematical reasoning based on the calculated paths of all comets which have been observed. That discussion is beset with great difficulties, and as yet points to no absolutely certain conclusion. The balance of testimony seems to favor the supposition, that comets originate outside the solar system. The planets move in nearly circular orbits about the Sun; and no one has been able to show why comets, if they have the same origin, should move in elongated orbits, entirely differing from those of planets.

Let us suppose, however, that all comets must have taken their origin from some primeval nebula from which a solar system has been evolved. It has been shown that the velocity of a comet may be so much increased by the disturbing action of a large planet, that it may escape from the control of the Sun, and be projected into the illimitable regions of space. Thus freed, it will go on in a straight line forever; unless, perchance, some powerful source of attraction, like another Sun, lying near its path, arrests its flight. The possibility of such an occurrence is by no means imaginary. At least one comet [Lexell's 1770] is supposed with good reason to have undergone that fate. There is every reason to believe that the same thing may have happened in other cases.

All argument drawn from observation and reflection prove that the stars which surround us on all sides are remarkably like our own Sun. Some of them are larger and even more powerful then he. Reasoning from analogy, we must suppose that these Suns are also attended by comets. Hence we are led to the conclusion that uncounted myriads of comets projected forth from

millions of Suns, during countless ages past, are now flying through space in every direction—restless messengers from star to star. By mere chance some of these bodies must come under the Sun's far-reaching power and be drawn into our planetary system.

The mass [quantity of matter] of comets is conceded to be very small in comparison with that of the earth. How small it is we cannot say. No comet has been found large enough to exert a sensible attraction upon any celestial body found in its vicinity. This fact confirms the conclusion derived from telescopic examination, that the real, solid nucleus, if it exists, must be extremely small.

It is certain that no body entirely gaseous could exist in space. The conditions for the stability of liquid bodies in their practical application to the explanation of cometary phenomena, are extremely complicated; since they are closely associated with the unknown elements—mass of the comet, solar radiation, and absolute temperature of space. It would also be extremely difficult to show how a swarm of small bodies could be preserved in a state of equilibrium, or resist the tremendous tidal action to which it would be subjected in the vicinity of the Sun. In fact, we must view the conversion of a comet through some unusual catastrophe, into such a swarm, as the sure precursor of approaching disolution. On the whole, it is probable there is a solid or partly liquid body near the center of the comet. This body is more likely to consist of an aggregation of loosely cohering pieces or particles, than of a single, firmly-united mass.

Owing to the smallness of their attractive force, comets cannot retain a sensible atmosphere. This conclusion is confirmed by telescopic observation, as we have seen.

If, now, we suppose the nucleus to be approaching the Sun, it will eventually reach a point where the liquid or other volatile matter on the "sunny" side commences to evaporate and be diffused about the comet. Without following the consequences of this evaporation into details, one can imagine for himself how the appearance of central condensation, of the streaming jets, and of the nucleus heavily obscured by vapors, might be produced.

To account for the backward curvature of the jets and the peculiar form and direction of the tail, we must look for some additional force. In all probability this force resides in the Sun, and is directly opposite in its effects to the power of gravitation. But since the body

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of the comet obeys the law of gravitation with sufficient fidelity, we must find a repulsion which sensibly acts only on the molecules of gas or vapor.

The only force suggested by experience as competent to these requirements is that of electrical repulsion. Anyone can prove for himself that two bodies similarly electrified mutually repel each other. We know that the earth through effects of constant evaporation and other causes is to some extent an electrified body. For the same reasons, we should expect comets to be electrified in a much higher degree. The Sun itself certainly exerts an influence upon terrestrial magnetism. Violent commotions upon his surface have occurred at the same time with unusual disturbances of the magnetic needle. Electrical repulsion acts in proportion to surfaces and not to volumes. On particles of matter in a state of infinitesimal subdivision it might act most powerfully, while not affecting a large body to an appreciable degree.

If, then, we suppose the Sun and comets to be sufficiently and similarly electrified, we have the force necessary to produce the backward curvature of the jets, and to drive off the smallest and probably outermost molecules of the coma to form the tail. Since, according to our hypothesis, very little matter can be given off from the shaded side of the nucleus, we readily perceive why the tail should be hollow in appearance.

The orbit of the moving nucleus being curved, it is evident that the particles driven off at any time with less than infinite velocity, would continually fall more and more behind the prolongation of a line through the Sun and comet—just as has been observed. If the matter contains molecules, varying considerably in size the larger ones would be driven off with less velocity. These would curve backward more than would the lighter molecules driven off at the same time; and so we have the multiple tails which have been seen, as well as the classification already described. Elaborate examinations of their average observed condition and form suggest that each class may be composed of chemical elements peculiar to itself. We may even venture to suppose that the tail of greatest velocity and least inclination is composed of hydrogen. The second type may contain carbon, with or without other elements; and among those of the third, chlorine would most likely be found.

It is a common error to suppose that this hypothesis, as to the formation of the tail, requires a repulsive force of inconceivable power. The straightest tails

which have been observed are accounted for by supposing a repulsive force not much greater than twelve times the Sun's atttactive power. The tails most frequently seen [scimeter-like in form] may be produced by a force about one-ninth of that amount, which is but little more than sufficient to overcome the attraction of gravitation.

It will be seen that it is equally erroneous to suppose any great amount of material wasted in the formation of the tail, when one reflects upon the transcendent lightness of its structure.

The influence of comets upon the earth is in all probability quite insignificant. They may, like the Sun, affect the earth's magnetic condition, and thus to some extent, possibly its meteorology. No such effect has ever been perceived. In spite of some chance coincidences between the apparitions of great comets and remarkable public events, no well-informed person now believes that there is any real connection between them. By a liberal and credulous interpretation of any frequently occurring celestial phenomenon, similar coincidences could be shown.

When a comet is converted into meteoric bodies, which impinge upon the earth's atmosphere, there is some direct though probably minute effect. Some have thought that a sensible portion of the heat which the earth receives is generated in this way; but the weight of scientific opinion seems to be against that hypothesis. The impact of meteors upon our atmosphere must add some matter to it, and this is probably in the form of dust, which has been collected at sea in recent times. The finer particles of it may have some influence on cloud formations, and other meterorological phenomena; but all this is merely conjecture.

A more remote effect may be sought in the possible fall of comets upon the surface of the Sun. Owing to his vast bulk, the Sun would attract an immense number of these bodies; but it is quite certain that their effect upon the Sun's heat is insignificant. It is now generally admitted that we must look for the origin of the Sun's heat in a constant, though to us, inperceptible shrinkage of his vast bulk.

Some connection between the frequency of Sun-spots and comets has been rather vaguely expected. Were the search for comets systematically pursued with equal persistence for a long period, we might have had some data for the formation of a sound opinion. Yet it would still be an open question whether comets cause the spots, or whether great activity of the Sun

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tends in some way to render comets brighter, so that more will be visible—with probability in favor of the latter supposition.

Finally, it may be said, with all due respect to scientific decorum, that the appearance of a great comet does exert one most happy influence on the earth, in that it stimulates the curiosity of mankind and directs their thoughts to the more particular contemplation of the glorious universe which surrounds them.

Astronomical Observatories in the United States.

Place.	Name.	Director.	Telescope.		
			Maker.	Aper. inch.	Powers
Albany, N. Y.	Dudley	L. Boss	Fitz*	13.00	
Alleghany, Pa	Alleghany	S. P. Langley	Fitz	13.00	50-1200
Ann Arbor	Detroit	M.W. Harrington	Fitz*	12.50	
Annapolis	U S. Naval	P. F. Harrington	Clark	7.75	40-966
Brooklyn, N. Y.	Private	G. P. Serviss	Byrne	3.38	50-320
" "	"	W. T. Gregg	Gregg	6.25	50-600
Buffalo, "	"	J. W. Ward	Byrne	4.00	60-400
Cambridge, Mass.	Harvard College	E. C. Pickering	Merz	15.00	100-2000
Cambridgport, "	Private	E. F. Sawyer	Bordan.	3.38	
Chicago, Ill.	Dearborn	G. W. Hough	Clark	18.50	120 900
Clinton, N. Y.	Litchfield	C. W. F. Peters	Spencer†	13.50	80-1600
Columbus, Mo.	Laws	Joseph Ficklin	Merz	7.50	80-1018
Columbus, O.	Private	R. W. McFarland	Clark	5.00	
Elizabeth, N. J.	"	C. W. Plier	Fitz	6.25	50-630
Fordham, N. Y.	"	W. Melkleham	Byrne	4.30	30-450
Ft. Dodge, Ia.	"	F. Hess		2.63	50
Glasgow, Mo.	Morrison	C. W. Pritchett	Clark	12 25	50-1200
Hanover, N. H.	Shattuck	C. F. Emerson	"	9.25	100-1200
Hastings, N. Y.	Private	Henry Draper [Reflector]	"	11.00	
			Draper	28.00*	
Haverford, Pa.	Haverford College	I. Sharpless	Fitz*	8.25	60-800
Hudson, O.	Hudson	C. J. Smith	Simnes	4.00	50-350
Iowa City, Ia.	Private	C. W. Irish	Cheval'r.	4.00	25-300
Linwood, O.	"	R. H. McClure	McClure.	5.50*	60-200
Madison, Wis.	Washburn	E. S. Holden	Clark	15.50	145-1200
Mt. Hamilton, Cal.	Lick	Not yet appointed			
Mt. Lookout, O.	Cincinnati	O. Stone	Merz*	11.25	90-1500
Nashville, Tenn.	Private	E. E. Barnard		5.00	52-520
New Haven, Ct.	Winchester	C. S. Lyman	Clark	9.00	40 620
Newington, Ct.	Private	D W. Edgecomb	Clark	9.40	2000
New York	"	L. M. Rutherford	Ruther'd	13.00	
Northfield, Minn.	Carleton College	W. W. Payne	Clark	8.25	50-800
Oxford, Miss.	State University	R. B. Fulton	Merz	4.50	96-312
Phelps, N Y.	Red House	W. R. Brooks	Brooks	5.00*	
Poughkeepsie, N.Y.	Vassar College	Maria Mitchell	Clark	12.34	200.600
Princeton, N. J.	College	C. A. Young	"	23.00	145-2800
Providence, R. I.	Seagrave	F. E. Seagrave	"	8.25	93-517
Rochester, N. Y.	Warner	L. Swift	"	16.00	45-2000
St. Louis, Mo.	Washington, Uni'ty	H. S. Pritchett	Fitz	6.25	76-456
S'th Bethlehem, Pa	Sayre	C. E. Doolittle	Clark	6.00	12-223
Tarrytown, N. Y.	Private	C. H. Rockwell	Hastings	6.34	60-751
Troy, N. Y.	Williams Proudfit	D. Greene	Fitz	3.50	45-200
Washington	U. S. Naval	John Rodgers	Clark	26.00	126-1600
			Merz	9.62	90-900
Washington, D. C.		[Eight Equatorials]	Clark	5.00	
Willets Point, N. Y.	Field Observatory	J. C. Mallery	Fauth	5.50	
Ypsilanti, Mich.	State Normal Sch'l	L. McLouth	Clark	4.00	45-210

* Clark. † Eaton.

CONSTITUTION OF THE SUN.

When astronomers speak of the Sun's *photosphere*, they mean its shining surface. There is close around the photosphere and just above it, a rose-colored sheet of gases. This layer is called the *chromosphere*.

When sun-storms are in progress the chromosphere is often greatly disturbed and the *red-flames*, *prominences* or *protuberances*, as they are called, assume most fanciful shapes and often move with astonishing velocity.

Above the *chromosphere* is a faint halo of pearly light, extending outward irregularly at considerable distances. This is the *corona*.

The following clear statement of the theory from Professor Young is the opinion of astronomers for the most part respecting the constitution of the Sun:—

1. The central portion is probably for the most part a mass of intensely heated gases.

2. The photosphere is a shell of luminous clouds, formed by the cooling and condensation of the condensible vapors at the surface, where exposed to the cold of outer space.

3. The chromosphere is composed mainly of uncondensible gases (conspicuously hydrogen,) left behind by the formation of the photospheric clouds and bearing something of the same relation to them that the oxygen and nitrogen of our own atmosphere do to our own clouds.

4. The corona, as yet, has received no explanation which commands universal assent.

SHORT-PERIOD COMETS.

Professor Swift, of Warner Observatory, kindly furnishes the following list of periodic comets, known to be such by a second return:

NAME.	PERIOD.	NAME.	PERIOD.
Encke	3.30 years.	Biela	6.61 years.
Tempel (1873)	5.16 "	D'Arrest	6.64 "
Swift	5.40 "	Faye	7.44 "
Winnecke	5.54 "	Tuttle	13.16 "
Brosen	5.58 "	Halley	76.00 "
Tempel (1867)	6.00 "	Denning, undoubtedly	38.00 "
Gould—(1843)—(1880)			38.00 years.

Fay's comet appeared in August last, but was very faint. Swift's is of recent discovery. Biela's has doubtless disappeared never more to return. Denning's was discovered last October, so that its second return has not been proved. The discovery is also claimed by

Mr. Brooks of Phelps, N. Y. Gould's is believed to be identical with the great comet of 1844. This list is believed to be correct to date.

COMETS OF 1881.

COMET *a* was discovered by Louis Swift of Rochester, N. Y., on the first day of May. It had a faint round disk with ill-defined edges and central condensation. It was less than one minute of arc in diameter. Its elements and ephemeris were computed by Mr. S. C. Chandler of Boston, and on the 7th day of May were cabled to Lord Crawford at Dun Echt, Scotland, as a test of the new cipher-code for telegraphic transmission of astronomical data. Two days later the elements and ephemeris computed at Dun Echt were received by cable at Boston. These tests of the code were successful.

The light of this comet at discovery was taken as unity. It was approaching the earth, and on May 20, its brightness was about three times that at the time of discovery. Its orbit was also computed by H. Oppenheim.

COMET *b* was the most wonderful celestial visitor we have had in a decade of years. It came into view so suddenly, and was so large and bright, people were led to think that astronomers were all asleep because no notice of its approach had been previously given. It was first seen in northern latitude by Prosper Henry at 3 o'clock on the morning of June 23, at the Observatory in Paris. The discovery was promptly cabled to Washington, and thence telegraphed to observatories in this country where it could be seen with the naked eye, on the same day. There was reason why it was not seen sooner, in any latitude. The comet passed from the southern hemisphere to the northern between the Sun and the earth, in a line almost perpendicular to the plane of the ecliptic. It was much nearer the earth than the Sun and its motion northward was rapid. For ten or twelve days following the discovery, astronomers were very active in observing and discussing the strange phenomena presented by it.

June 26, $10^h\ 30^m$ Rochester mean time, Professor Swift saw a right-lined streamer from the train near the *coma*, about twice the length of the comet's tail.

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W. Doberck of Collooney, Ireland, by the aid of the Markree refractor made drawings of this comet representing the changeful state of the nucleus, June 25-27, and published the same in the *Astronomische Nachrichten*. Professor E. S. Holden of Madison, did similar work, as favorable sky would allow, between June 24 and July 8, and eight drawings were published in *Science* and *The American Journal of Science*, detailing wonderful changes in the *coma*.

Professor Lewis Boss of Albany, published a series of notes and four drawings of this comet in the October number of the *American Journal of Science*. The two branches of the tail and the extent to which they resemble what are called the normal types of cometary trains are therewith fully presented.

Professors Stone and Wilson of Cincinnati, gave special attention to the nucleus of this comet from June 23 to July 7. Their notes and drawings, though not yet published in any complete way, are known to be full and valuable. Their drawings made by the aid of the 11½-inch refractor on the evening of July 6, plainly show a division in the nucleus of surprising extent.

June 24, Professor Draper of New York, photographed this comet. Subsequently by an exposure of the plate for two hours and forty-five minutes he obtained a picture showing the tail ten degrees long. There were many stars on the plate—some shining through the tail. On the same day, Dr. Huggins of London, obtained a fairly good photograph of the spectrum of this comet, the exposure being one hour. This is important as it is claimed to be the first photograph of a comet's spectrum ever secured. It showed a pair of bright lines in the ultra-violet region corresponding with the two lines in the spectrum of carbon. The Fraunhofer lines of the continuous spectrum were also well seen, showing the dark lines G h H k and others. This portion of the light of the comet is from the Sun. Liveing and Dewar have shown that these groups of bright bands indicate the presence of nitrogen as well as carbon and hydrogen. According to Dr. Huggins the same was true of the comets of 1866 and 1868.

At Greenwich, observations of the comet's head, with a half-prism spectroscope, gave a bright continuous spectrum, with four bright bands in the yellow,

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green, blue, and violet, respectively. Several measures of these bands indicate the presence of carbon in some form.

Professor Young of Princeton, says the visible portion of the spectrum of this comet agrees with the so-called *first* spectrum of carbon obtained from the flame of the Bunsen burner, and not with the *second* which is given by a Geissler tube containing carbonic acid or some hydro-carbon vapor.

In this, we have very strong evidence that the gaseous substance of this comet is a hydro-carbon and in a molecular state, like that at the base of a gas-flame.

June 26, Nicolas de Konkoly of Ostend, examined the comet in regard to its telescopic appearance, and to the polarization of its light. A secondary *coma* was seen, and also two different kinds of radiation. The nucleus was oval, its greatest axis lying north and south. In the Savart polariscope magnificent lines appeared, being intense on the western side of the tail and faint on the opposite side. The fact of polarization of light shows that the comet shines by reflected light, in part at least.

Professor Arthur W. Wright of Yale college, observed the comet June 29. A Savart plate was attached to the Nicol's prism in the eye-piece, giving a narrow field which was nearly filled by the image of the comet. This arrangement was very favorable for detecting the bands caused by polarization. The plane of polarization of the light was found to have such a direction as to pass through the Sun's plane. This was determined in two different ways; first, by the disposition of the bands seen in the polarimeter, and *second*, by means of a double-image prism placed before the ordinary eye-piece of the telescope. Professor Wright thinks it is probable that the constitution and physical condition of the matter composing the tail of this comet were variable, and that the greater part of the light which came from the tail was reflected sunlight.

O. C. Wendell of Harvard College Observatory, July 24, observed that the nucleus was much elongated with a marked inclination to separate into two parts, about equally bright, where there was also another portion somewhat fainter that attracted attention. The view was the same under different powers.

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Though it cannot be said that there was actual division, yet it is certain that the nucleus was notched, and that a faint dark line was traceable, at times, showing a tendency to separation.

Micrometrical measures were made at this date with the following results:—

Position angle of elongation, 226° or Southwest 60?

Total length of elongation, 11″.8 or about 5,000 miles.

Total length of nucleus, 10″.9 or about 4,500 miles.
Breadth of nucleus, 5″.4 or about 2,200 miles.

July 26 the comet had substantially regained its normal conditions.

Mr. Hind, of England, and Mr. Chandler, of Boston, each computed the parabolic elements of this comet and the results as published agree very closely.

So far as is known, comet *b* was last seen on the 18th of Jauuary, 1882, being in view continuously for seven months nearly.

Comet *c* was discovered by Mr. Schaeberle, of Ann Arbor, July 16. It had a stellar nucleus and was less than two minutes of arc in diameter. July 18, its brightness was taken as unity in the elements and ephemeris computed by Dr. Hepperger of Vienna. Aug. 16 the comet passed very near (theta) of *Ursa Major*, a star of the third magnitude, and its brightness was then equal to that of the star. The same day Professor Wright, of Yale college, with the polariscope before described, observed this comet. Its light was easily seen to be polarized by three different persons in the plane passing through the Sun. The light was just sufficient to enable the bands to be seen with great difficulty.

Nicolas de Konkoly, July 25, saw the spectrum of this comet as a faint continuous one. There also appeared a spectrum of lines with three tolerably bright bands which ended in spires, the middle of each being swollen. The spectrum as a whole closely resembled that of the comet Pechule.

The elements of comet *c* were computed by Drs. Copeland and Lohse from observations made at Vienna and Dun Echt. Also by Professor Stone of Cincinnati.

Comet *d* was the return of Encke. It was found by

Mr. Common of England, Aug. 27, and was very faint, being about two minutes of arc in diameter. It was not brighter then a star of the tenth magnitude.

COMET *e* was discovered by E. E. Barnard, of Nashville, Tenn., Sept. 19, and was estimated to be as bright as a star of eight and one-half magnitude. It was circular, about one minute in diameter, with a decided central condensation. Its light on September 29 was taken as unity. Its orbit was computed by S. C. Chandler, of Boston, and does not resemble that of any other known comet. Karl Zelber of Wien, Austria, also computed parabolic elements and ephemeris which fairly agree with those of Chandler.

COMET *f* is credited to W. F. Denning, of Bristol, England, as discoverer. It having been found Oct. 4, at 15^h. W. R. Brooks, of Phelps, N. Y., claims to have discovered this comet independently, Oct. 4, $2^h\ 45^m$, P. M. T., but that clouds obscured it before a position could be obtained. It was about the brightness of a star of the tenth magnitude. Elliptic elements of the orbit of this comet were computed by Chandler and L. A. Schulhof. The former made its period about eight years, the latter seven and three-fourths years.

Oct. 19, Mr. Denning wrote to the Astronomer Royal of England, as follows: "Will you allow me to suggest to English observers, who like myself, have the necessary time and instruments, that we should make some attempt to enter into friendly competition with foreigners in the field of cometary discovery? It is certainly remarkable that we invariably allow the first intimations of such discoveries to come from abroad."

COMET *g*, the seventh and last of 1881, was discovered by Professor Swift of Rochester. It was a faint telescopic object, and is thought to be identical with comet I, 1792, discovered by Caroline Herschel. Chandler computed its parabolic elements.

ELEMENTS OF COMETS OF 1881.

Name.	Perihelion.	Long. Perih'n	Long. Node.	Inclination.	Log q.	Computer.
Swift (a)... ..	May 20.67 G. M. T.....	300° 2′	124° 54′	78° 48′	9.7674	Copeland.
Gt. Comet(b)	June 19.4 G. M. T.....	265° 8	270° 59′	63° 31	9.8657	Chandler.
Schæberle (c)	Aug. 11.63 B. M. T.....	226° 35′	104° 39′	144° 49	9.7925	Hepperger.
Encke (d).....	July 2.0 B. M. T.....	153° 30′	334° 34′	12° 53		
Barnard (e)...	Sept. 13.97 B. M. T.....	278° 36′	270° 2 .	113° 26	9.6864	Zeblr.
Denning (f)...	Sept. 12.83 G. M. T.....	18° 10	66° 9′ .	6° 59′	———	Chandler.
Swift (g).....	Feb. 5.35 '82 W. M. T...	38° 11′	205° 45′	13°446′	0.1496	Chandler.

G. M. T. means Greenwich mean time, B. M. T. Berlin mean time, W. M. T. Washington mean time.

THE SUN.

Professor C. A. Young's excellent work on the Sun recently published by the Appleton's contains the following interesting summary:

Solar parallax (equatorial horizontal), $8''.80 \pm 0.02$.

Mean distance of the sun from the earth, 92,885,000 miles.

Variation of the distance of the sun from the earth between January and June, 3,100,000 miles.

Linear value of 1″ on the sun's surface, 450.3 miles.

Mean angular semi-diameter of the sun, $16'\ 02''.0 \pm 1.''0$.

Sun's linear diameter, 866,400 miles. (This may be variable to the extent of several hundred miles.)

Ratio of the sun's diameter to the earth's, 109.3.

Ratio of the sun's surface to the earth's, 11,940.

Ratio of the sun's volume to the earth's, 1,305,000.

Ratio of the sun's mass to the earth's, $330,000 \pm 3,000$.

Ratio of the sun's mean density to the earth's, 0.253.

Ratio of the sun's mean density to that of water, 1,406.

Force of gravity at the sun's surface compared to that of the earth, 27.6.

Inclination of the sun's axis to the ecliptic, $7° 15.'$

Longitude of its ascending node, 74°.

Mean time of the sun's rotation, 25.38 days.

Time of rotation of the sun's equator, 25 days.

Time of rotation in latitude 20°, 25.75 days.

Time of rotation in latitude 45°, 27.50 days.

(The last three numbers are somewhat doubtful; because authorities differ several hours in some cases).

Linear velocity of rotation at the sun's equator, 1.261 miles per second.

Total *quantity* of sunlight, 6,300,000,000,000,000,000,000,000,000 candles.

Intensity of light at the sun's surface, 190,000 times that of a candle flame; 146 times that of a calcium-light; 3.4 times that of an electric arc.

Ratio of the brightness of the sun's limb to that of the center of the disk, 25 per cent.

Thickness of a shell of ice that would be melted on the surface of the sun per minute, 48½ feet.

Mechanical equivalent of the solar radiation at the

Sun's surface, continually acting, 10,000 horse power per square foot.

Effective temperature of the solar surface (Rosetti), about 18,000° Fahrenheit.

TIME SERVICE OF CARLETON COLLEGE OBSERVATORY.

The Observatory of Carleton College is located at Northfield, Minn., forty miles south of St. Paul, on one of the main lines of the Chicago, Milwaukee & St. Paul railway. The building was erected in 1878. Its latitude was determined by Prof B. F. Thomas (now of the University of Missouri,) in 1879, by a series of observations made with a two-inch Wurdemann zenith telescope, loaned to the Observatory for that purpose, by Lieut. Edward Maguier, Chief Engineer of the Dept. of Dakota. By using the Talcott method, Professor Thomas found the latitude of the Observatory to be 44° 27′ 41″±. During August, 1880, the work was done again by another person using the same instrument and method, observing forty pairs of stars, on different nights, with mean places from Safford's catalogue. After the proper reduction the latitude was found to be 44° 27′ 40″.8. These two determinations of the latitude, being a year apart in time, and wholly independent of each other were in surprisingly close agreement. In Oct., 1880, by the aid and courtesy of the officer last named and Lieut. O. B. Wheeler of the Lake Survey, the longitude of the Observatory was determined, the Coast Survey meridian of the St. Paul being used as the base of operation. Observations were taken at Northfield and St. Paul on succeeding nights, and telegraphic signals were exchanged. Independent reductions of these observations showed the longitude of the Observatory to be $1^h\ 4^m\ 23^s.8$ west of Washington, and $14^s.3$ west of the meridian of St. Paul.

The Observatory is furnished with the following instruments:—

A Clark equatorial, 8¼ inch aperture, 10½ feet focal length, with complete mounting.

A Byrne equatorial, 4.3 inch aperture, with portable mounting.

A Transit, made by Fauth & Co., Washington, 3 inch aperture and 42 inches focal length, with revers-

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ing apparatus; two Howard clocks, with electric and magnetic attachments for regulating and distributing time; a Bond sidereal chronometer with break-circuit attachment, and an ordinary Clark chronograph.

The time-service of the Observatory began Oct. 23, 1878, immediately after the new clocks were regulated, the Northwestern Telegraph company (now Western Union) having previously asked for the time, and having run a telegraph line to the Observatory and furnished it with an office.

The daily electrical time-signals, are given by the mean-time clock itself, which has a break-circuit attachment operated by a small wheel on the shaft of the seconds hands which has thirty-one teeth spaced to represent two seconds of time except *three*, which give continuous seconds, to mark the close of each minute. This clock is placed in a local circuit with appliances for cutting it into the main telegraph line for daily noon signals.

By arrangement with the railroad companies our mean-time clock is put into line daily at eleven o'clock and fifty-seven minutes, so that *three* full minute signals may be given, the last stroke of the third minute being understood to mark the time of twelve exactly. Until quite recently the distriburion of the time to the railroads has been effected in the following manner:—

The principal offices of resort of the companies' terminating lines in St. Paul and Minneapolis have wire connection with the main office of the C. M. & St. Paul railway for the purpose of time. In this way the Observatory clock has daily given its three-minute signals over the main lines of these companies. The branch lines use the same time, but it is repeated over them by hand. When the main lines are thus connected the clock has given it break-circuit signals or 2,000 miles of wire in six different states and territories, ranging from Kansas City to St. Paul, Winona and McGregor, of Iowa. In September, 1881, the signal was modified by reversing the points of the relay in the local circuit, for the purpose of a *make-circuit* signal on the main lines. A five-minute signal attachment has also been applied to the clock that time-balls may be dropped, at noon, daily in connection with the railroad time-service. This five-minute attachment, as it is called, is a plain disk, connected with the train of the clock so as to re-

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volve once in five minutes, and a portion of the circumference representing fourteen seconds is cut away. It is, of course, in the local clock-circuit and serves to keep that circuit closed, and hence the main line open during the fourteen seconds preceding the *sixtieth one* before noon. This interval of open line gives opportunity to connect time-balls with electrical apparatus for dropping the same by the single noon stroke of the clock.

The following railroad companies take the Northfield meridian time directly or indirectly, and use it over their lines with or without local change:—

1. C., M. & St. Paul Ry. on its five divisions west of the Mississippi river, embracing an aggregate length of	2271
2. W. & St. Peter Ry. (branch of the C. & N. W. Ry.) uses both Northfield and Baraboo signals but runs on Northfield time.	453
3. C., St. P., M. & O. Ry., from Sioux City to Elroy, Wis., on all its branches	1057
4. M & St. L. Ry., from Minneapolis South	361
5. Northern Pacific to end of track west in Montana	1033
6. St. P., M. & M. Ry., to Winnipeg possibly, to St. Vincent certainly	1025
7. St. Paul & Duluth to head of Lake Superior	153
Total number of miles	6353

The last two companies named do not take time directly from the Observatory, but from jewelers in the city of St. Paul, who receive our daily signals. It will be readily understood, that the territory traversed by these great railroads embraces all of Minnesota, and parts of Iowa, Nebraska, Dakota, Wisconsin, Montana and possibly the province of Manitoba.

In the month of January last, a time-ball service was undertaken for the city of St. Paul a distance of forty miles, almost due north of the Observatory. By the courtesy and the generous aid of the Western Union Telegraph company, wire connection with the Observatory was secured and is maintained to a prominent business center in the city. On the roof of the Fire and Marine building a staff thirty-three feet long was erected, having a cross-piece and pulleys at the top. Over the pulleys, ropes pass which are attached, at one end, to the ball and extend downward through a tin-lined aperture in the roof to the electrical dropping apparatus below. This apparatus is an ordinary telegraphic relay with a strong spring and knee-joint oper-

ated by the armature of the relay, when connected with the astronomical clock of the Observatory at Northfield.

At 11^h 57^m each day, an electrical bell within the case of this apparatus gives the notice, by continuous, alternate second strokes, that the time-signal is coming. The person in care of the ball turns a switch, throwing the apparatus out of line, raises the ball by hand, sets the dropping spring, and connects the rope. At fifteen seconds before noon, the astronomical clock at Northfield opens the telegraph line, and the electrical bell is silent, which is notice to switch the apparatus again into line. At twelve o'clock exactly the clock closes the telegraph line and the electrical impulse frees the rope through the armature, and the ball falls of its own weight. The dropping apparatus was made by Prof. H. S. Pritchett, of St. Louis. It is neat, simple and effective.

The ball used is three feet in diameter, made of heavy wire, covered with canvas and painted black. It is hollow, with apertures at the top and bottom, one foot in diameter, through which the staff passes. The ball was made by Sheire Bros., of St. Paul. The success of this project has been due chiefly to the energy and public spirit of Mr. Thos. Cochran, of St. Paul, generously aided by Supt. McMichael, Manager Curry, and Chief Operator Wilson of W. U. Tel. Co., and Mr. John Ryan, Train Dispatcher of C. M. & St. Paul Ry. Mr. H. E. Thompson, of the St. Paul Electrical Works, has also freely given valuable aid in the beginning of the service, and he now has the immediate care of the apparatus and the daily attention that the ball-service requires. Arrangements are already made for a like time-ball service in the city of Minneapolis, to be perfected in a short time.

This paper will be devoted to the interests of Astronomy, as its names implies. It is in no sense a rival for the place or the patronage of such periodicals as the *Nachrichten*, *Urania*, *Observatory*, and other leading periodicals that might be named. Those worthy papers go mainly into the professional walks of the science. The practical astronomer needs just such aid as they furnish, and he must now have it, and the re-

sult is a liberal support for them. Our aim is somewhat different. There are other public interests to serve besides those that are mainly theoretical, or professional; for there are persons, not a few, in every vocation of life, that have a love for the elements of this great science, and they will inform themselves respecting its general progress, if it can be done at reasonable cost. Our purpose then, is to select that which is best, new or useful, from the mass of work that is now going on in the various branches of astronomy everywhere, and present the same in a terse and plain way, avoiding the use of technical terms, and the details of research as much as possible, that all persons interested may read with care and profit. The first number of the MESSENGER which is now respectfully offered, must mainly, speak for itself.

Teachers of astronomy, in colleges and high shools, have not usually the means of knowing the kind or extent of work carried on in observatories in this country and abroad; neither do they generally have access to the many periodicals now published in the interest of astronomy. It is also known to some instructors that most of the text-books on astronomy, now in use, are quite erroneous in detail. Knowledge that is fresh and direct from these original sources must be of special value to this class of persons, in view of what is rightfully expected of them as faithful instructors. Our advantages to furnish this needful aid are ample. We are in telegraphic communication with the Smithsonian Institution at Washington, from which is distributed promptly, by wire, all important astronomical discoveries from all parts of the world. By the courtesy of a liberal friend connected with the Naval Observatory at Washington, a condensed statement of foreign news and work in astronomy will be supplied regularly, in the future. In the matter of news and brief articles astronomers so far as we have had opportunity to confer with them, seem ready and very cheerful, to lend a helping hand to this enterprise.

In order to have knowledge that is somewhat definite respecting the work that is now going on in this

country, the student of astronomy should know something of the men engaged in it, the instruments they use, and their places and methods of observation. As a beginning in this line of thought, we publish elsewhere a list of the observatories in the United States, containing the place where the Observatory is located, its name, the name of the director, size of clear aperture, highest and lowest powers used, and the name of the maker. This table is known to be incomplete. It will, however, be supplemented as soon as the necessary information is received. Reference marks in the column of maker, indicate the names of other persons below who have also done important work on the same instrument.

During the last year, Mr. Warner of Rochester, N. Y., the founder of the Warner Observatory, offered a special prize of $200 for the best essay on *Comets, their composition, purpose and effect on the Earth.* One hundred and twenty-five essayists competed for the prize. The judges were Professor E. Colbert, of Chicago, Professor H. A. Newton of Yale college, and Professor H. M. Parkhurst, of New York city. They unanimously awarded the prize to the essay signed Hipparchus III. This paper was prepared by Professor Lewis Boss, director of the Dudley Observatory at Albany, N. Y. It is herewith presented to our readers, and is printed in full, because it is believed to be the best brief statement of what is known of comets at present.

Professor Pickering of Harvard College Observatory, has recently ordered a stellar spectroscope from Mr. Hilger of London, which is to be used in determining the distribution of the light in the spectra of the banded stars, as they are called. He is also planning to use the photometer in measuring the brightness of a list of regions on the surface of the moon, to be taken as light standards generally.

Mr. Chandler of Harvard Observatory, has undertaken an important piece of work. The references to observations of stars of known or suspected varia-

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bilty, have been collected, and those of each star brought together. This portion of the work is now more than half completed. The next step is to measure comparison stars photometrically, and then all observations will be reduced to a uniform system, which will include finally the work on variable stars of long period, also.

The large equatorial telescope in process of construction for the Halsted Observatory of Princeton College, is nearing completion. The Clarks finished the object-glass more than a year ago. Its clear aperture is twenty-three inches, with a focal length of twenty-nine and one-half feet. The powers of the eye-pieces range from 145 to 2800. The optical qualities of the objective are said to be excellent. The instrument is to be mounted in the dome of the Observatory, which has a diameter of thirty-nine feet. The spectroscope to be used with this noble instrument is now being made by Mr. Hilger of London, under the supervision of W. H. H. Christie, Astronomer Royal of England. It is constructed on the half-prism plan, the focal length of its collimator being three feet, and its aperture two and three-fourths inches. The whole cost of telescope and spectroscope with accessories, is $26,000. Under the guidance of Professor Young as director, such facilities for astronomical work will certainly yield early useful results.

In 1880 there was organized in Winchester Observatory of Yale College, a horological bureau with a special equipment of instruments for a regular and extended public time service. The standard time, by law of the state, is that of the meridian of the City Hall, New York. Another important work of the bureau is to test watches and chronometers in the interest of watch-makers, for which special facilities have been provided. There is also connected with this observatory, a bureau in charge of Dr. L. Waldo, for the verification of clinical and other thermometers. Since June, 1880, this bureau has examined 1957 thermometers, and issued appropriate certificates for the same. In the summer of 1880, the observatory contracted with Messrs. Repsold of Hamburg, for the construction of a heliometer. It will be completed in a few

days. The cost of the standard instrument is about $7,500. The object-glass is six inches and its focal length eight feet. Professor Newton says that the mounting has several new features suggested by experience. The parts of the object-glass move on arcs of circles, and readings are made from the eye-end of the tube by telescopes. The heliometer is an instrument hitherto unknown in the United States, and is designed for exact measurements rather than optical discoveries. It will be used in the coming transit of Venus.

The Observatory of Cincinnati, under the direction of Professor Stone, for years past, has offered to young men of sufficient advancement in mathematics, very unusual advantages for study in practical and theoretical astronomy. Those who have been there, enthusiastically say that the kind of instruction given, gratuitously, for the most part, and the facilities enjoyed in elementary work as well as the more intricate, are helpful and excellent.

Professor Hall of the Naval Observatory at Washington, in July, published an ephemeris of the satellites of Mars for the opposition of 1881, in No. 2394 of the *Nachrichten*, Dec. 14 was named as the time when the satellites would appear brightest, although they would be only three-tenths as bright as at the time of discovery in 1877. This is owing to the greater distances of the planet from the earth and the sun. The satellites were observered in Washington during December, and both were seen near the places computed for them as before stated. Professor Hall says: "Both satellites were brighter than I expected to see them, and they could be observed with ease." They were probably not seen after Feb. 1.

J. Palisa, director of the Naval Observatory of Austria at Pola, has recently discovered two planetoids. The first was announced January 18, 1882, as a star of the eleventh magnitude, and the second was discovered Feb. 9, and is not brighter than a star of the thirteenth magnitude. The number of minor planets is now 222.

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NOTES.

E. E. Barnard of Nashville, Tenn., has made a drawing of Merope, Nebula in the *Pleiades*. His notes on this and other work will have early attention.

The new double stars discovered by Mr. Burnham while at Chicago, Madison and Mt. Hamilton, California, which have not yet been published, number about two hundred in all.

The cipher code for the telegraphic transmission of astronomical data, recently devised by those in charge of the *Science Observer*, is attracting general attention. A full account of it will soon be given.

An interesting letter was recently received from Mr. F. Hess, of Fort Dodge, Ia., respecting the work of last year with small instruments, and the coming transit of Venus. His suggestions and plans for local observation of the transit, will receive notice in a later number.

The foundation for the new Observatory of Beloit college, was completed last fall. A sextant, a sidereal clock and a transit instrument have been received already. The erection of the Observatory building and the setting of the instruments, will be under the immediate direction of Professor T. A. Smith.

Professor Holden, of Washburn Observatory is introducing the Dudley controlled electrical clocks into his system of time-service. A full description of it will appear soon.

S. W. Burnham is again at Chicago, and is continuing the double-star work with the Dearborn equatorial.

Professor Hough's observations of Jupiter extend over a period of three years, and promise valuable results.

Shattuck Observatory of Dartmouth college is under the direction of Professor C. F. Emerson, since the resignation of Professor Young. Observations of sun-spots and the use of instruments for class illustration is nearly all that Professor Emerson has time to do in view of required duties in other departments.

The work at Ann Arbor in charge of Professor Harrington is classed under five heads:

1. Search for, and observation, of, new bodies.
2. Time and position (R. A. and Decl.) of stars.
3. Instruction—practice for students.
4. Continued meteorological observations.
5. Micrometrical observations—at present corresponding occultations of moon for Signal Service.

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W. W. PAYNE, EDITOR.

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